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Trimaran Hull Form Optimization Using Shipflow®

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Abstract:
Trimaran is the most promising hull form for naval vessels because of its excellent performance characteristics notably reduced wave making resistance, larger deck area, good sea keeping and ability to perform optimally in a range of speeds. In its most generic form it consists of a slender centre hull and two side hulls. High slenderness ratio, differential breadth to draft ratios, stagger/separation of the hull forms gives an edge over equivalent monohulls/catamarans in minimising wave making resistance. However it's further possible to reduce the wave making resistance by means of advancements to the existing design which can include bulb & wave piercing forms, stern wedge/flap/interceptors, asymmetry in side hull configuration , lifting bodies etc. The present paper investigates the qualitative performance of trimaran hull form modified to various configurations using Shipflow®.

1.Introduction

Trimaran is gaining popularity in the recent times as it provides a series of advantages over the conventional monohulls and catamarans. These benefits range from lesser wave making resistance, larger deck area to better stealth properties.

The advantages of trimaran over other hull forms in terms of hydrodynamics is contributed by its slender centre hulls (L_m/B_m>12), slender side hulls (Ls/Bs>15) and as well as their relative positing in longitudinal and transverse plane. The three hulls in a trimaran results in higher wetted surface compared to mono-hulls and catamarans. This increases frictional resistance resulting in higher resistances at low speeds. At high speeds, the combination of slender hulls and optimum positioning of side hulls can result in low wave-making resistance. Thus beyond Fn ~ 0.30, where residuary resistance dominates, its reduction can far outweigh the penalty for increased wetted surface. The position of side hull is a major determinant in the wave making resistance. So the first step in optimization of Trimaran hull is to determine the optimal location of side hulls. An significant studies have been conducted on the optimization of the position of side hull both experimentally and computationally [1][2] and results have suggested that benefits of a particular position are not uniform in the entire range of Froude nos. However, it can be concluded that more aft wards is the side hull, lesser is the wave making resistance and in general more widely the side hulls, lesser is the wave making resistance. But wider transverse separation always does not behave alike in reducing the wave making resistance. The interaction of wave system generated by the centre hull with that of side hull have an important impact on the total wave making resistance From the independent studies carried out at Naval Postgraduate School, Monterey, California [2] and Stevens Institute of technology [1] to optimize the location of side hulls, it can be clearly observed that wave making resistance coefficient (Cw) is minimum for aft most location but not for maximum separation.

Also, Hongxuang Peng[5] discusses studies done on trimaran with different hull forms form which concluded

that trimaran with side-hulls aligned with the stern (zero stagger) normally would produce smaller wave resistance coefficient(Cw) than that with the side-hulls aligned with the middle of the hull for Fn = 0.35 to 0.55. Studies at *Dipartimento di Ingegneria Navale (DIN)* [6] evaluated a trimaran hull configuration for a displacement of 28000 m3, that reaches a service speed of 36 to 40 knots (Fn = 0.285 and 0.397). It was observed that the trimaran configurations achieve a reduction of about 20 % of Cw with respect to no-interference condition. At 32 knots, forward positioning of the side hulls seem to give favourable powering conditions; at 40 knots the zero stagger positioning give the best performance.

Further it is also possible to optimize the trimaran for lesser wave drag by carrying out modification in hulls like wave piercing forms, reducing length of side hulls (displacement constant), etc. Experimental studies done by Daniel J. Lyons et al. at Naval Surface Warfare Center, Carderock Division [3] on trimaran hull form fitted with wave piercing forms. The results showed a considerable reduction in the overall resistance.

Trimaran wave making resistance is sensitive to relative positioning of its hulls, modifications to individual hulls It can be understood from the fact that the +ve/-ve interference of the wave system generated by a trimaran decides its optimal hydrodynamic behaviour. So a minor change in positioning of individual hulls and modifications can alter the resultant wave system and thus the interference resistance.

In relation to hydrodynamic design of the optimal hull form for a trimaran at Naval Science and Technological Laboratory, Vishakhapatnam, intensive computational and experimental studies were carried out, first the optimal stagger and separation was arrived for the base trimaran and then a series of modifications were carried out for centre hull as well as for side hulls. This paper summarizes the comprehensive study that has been carried out to optimize the trimaran hull form using Shipflow®

2.Trimaran Hull Details

The centre hull has an L/B ~12 & side hull has L/B ~20. The side hulls are approximately 52 % of the length of the centre hull. Table 1 & Fig 3 give the details and view of hull forms.

Measurements	**Values**	
	Centre Hull	**Side hull**
Δ/L^3	0.00126	0.00071
L/B	12	20
B/T	2.5	1.5
Cp	0.684	0.684
Cb	0.498	0.498
Cm	0.783	0.783
Cwp	0.807	0.807

Table 1: Measurements of centre hull & side hull

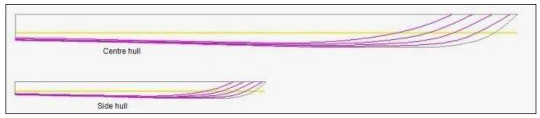

Figure 1: Profile view of Centre hull and Side hull

3.Trimaran Hull Optimization

3.1.Optimization Philosophy

The optimization was carried out with the goal of achieving lesser wave making resistance and other characteristics like seakeeping, manoeuvring etc were not taken into consideration in this phase. Wave making resistance coefficient (Cw) was computed using potential flow analysis in Shipflow® for various configurations and were compared

First the analysis was carried out to determine the optimal stagger and separation of the side hulls. A series of modifications for centre hull, for side hull and combinations were performed which will be discussed in detail in subsequent sections.

3.2.Shipflow® Inputs

The potential flow analysis module "XPAN" of Shipflow software was used to perform the studies. It contains two modes of mesh - auto and manual. In auto mode user just need to enter offset file and a set of commands and software by default will generate body and free surface mesh required for computation. However, in case of trimaran auto mode has limitation and the user is directed to use manual mesh mode. The meshing parameters have to be manually feed by user. The offset file was prepared in such a manner that its offsets, draft conditions are non-dimensionalised by LBP parameter. Since Cw is independent of scale, it made no difference in the obtained results. Also the scaling was done in such a manner the displacement was constant for every configuration. The major challenge was to decide the meshing parameters for which Shipflow® gives the accurate results because when computation was performed by feeding different values the results were quite different from each other. To solve the problem model test results of trimaran done at High Speed Towing tank, NSTL were considered. Numerous computations were performed by varying meshing parameters and then the meshing for which results were more close to the model tests results were adopted as the standard one. Table 2 shows the standard meshing parameters used. This meshing was used as a benchmark and was proportionately adjusted for any modifications in configurations. For example while analysing side hull with reduced length (35 % of centre hulls), grids on side hulls were also reduced accordingly.

xflow
title(title = "Trimaran")
program(xmesh, xpan)
vship(fn = [0.5], rn = [0])
hull(trim)
offset(file = "as_Trimaran ")
end
xmesh
body(grno = 1, offsetg = "sidehull", ytra = -0.0822, station = 31,
point = 7, str2 = 5, df2 = 0.01, dl2 = 0.02)
body(grno = 2, offsetg = "sidehull", ytra = -0.0822, ymir, station = 31,
point = 7, str2 = 5, df2 = 0.01,dl2 = 0.02)
body(grno = 3, offsetg = "CH", xtra = -0.49, station = 61, point = 14,
str2 = 5, df2 = 0.01, dl2 = 0.02)
free(grno = 4, point = 5, str1 = 5, df1 = 0.005, dl1 = 0.005, nbd2 = 1,
ibd2 = [3], nbd4 = 1, ibd4 = [2], y4side = -0.0822, xups = -1, xbow = 0,
xste = 1, xdow = 3, stau = 35, stam = 35, stad = 105)
free(grno = 5, point = 20, str1 = 1, df1 = 0.02, nbd2 = 1, ibd2 = [1],
y4side = -1, xups = -1, xdow = 3, stau = 35, stam = 35, stad = 105)
transom(grno = 6, point = 3, nbd1 = 1, ibd1 = [3], stad = 11)
transom(grno = 7, point = 3, nbd1 = 2, ibd1 = [1,2], stad = 21)
end
xpan
control(free, linear, eqavfa = 0.001)
iterati(maxit = 20)
parall(nthread = 2)
end

Table 2: Sample Shipflow® command file

3.3.Optimal Stagger and Separation

The Stagger and separation are defined as shown in Fig 5. Both are defined in terms of % of overall length of centre hull (L_{OA})

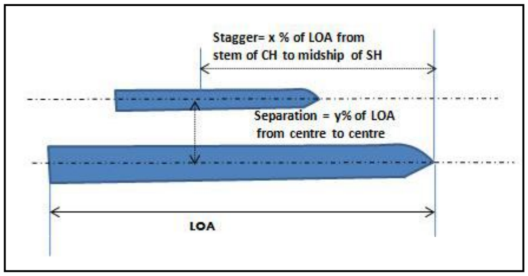

Figure 3: Stagger and separation definition

A total of nine cases were considered for computation for various combinations of stagger and separation as provided in Table 3. First the effect of Stagger was studied by fixing the separation to 8.3 %. The results (Fig.6) showed that Cw is minimum for the 75 % stagger in the interested range of Froude no.

	Stagger		
Separation	**75 %**	**59.8 %**	**45 %**
8.3 %	C-1	C-2	C-3
9.4 %	C-4	C-5	C-6
10.2 %	C-7	C-8	C-9

Table 3: Various cases for computation
**"C" is Acronym for Case*

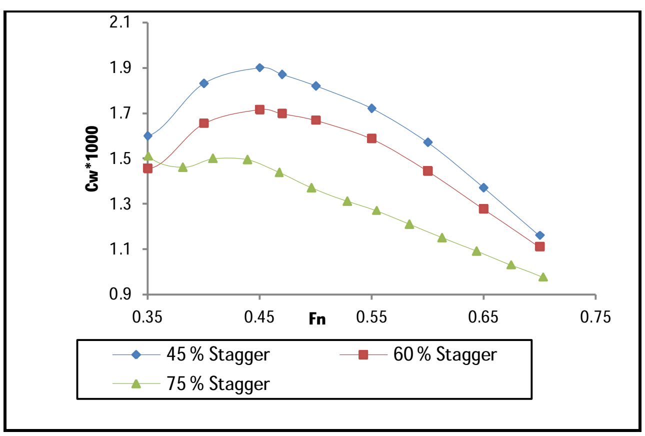

Figure 4: Cw vs Fn (Separation = 8.3 %)

Since it was known through the literature survey that effect of stagger is more prominent and difference in Cw due to stagger can't be compensated by difference in separation in general, 75 % stagger was adopted as the optimal stagger and then computation was done for different separations. Other cases were not run. So a total of 6 cases were run in place of estimated 9 runs.

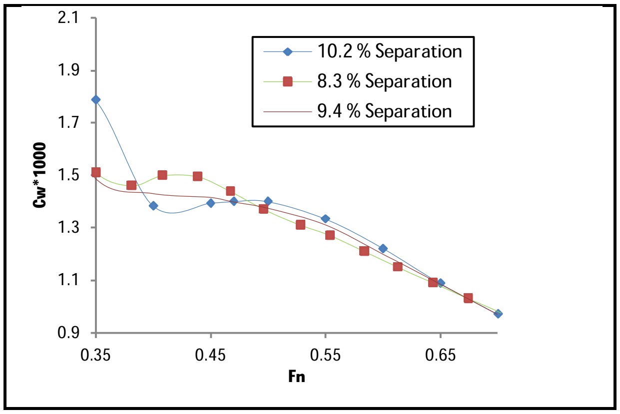

Figure 5: Cw vs Fn (Stagger = 75 %)

It was observed that in the interested range of Froude no 75 % stagger and 8.3 % separation gives the minimum Cw and thus the same was adopted as the optimal configuration for further cases studies. Fig 6 shows the wave contour for this configuration at Fn= 0.5

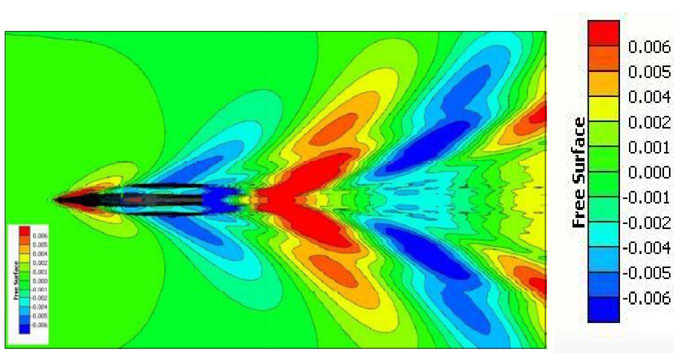

Figure 6: wave contours at Fn=0.5

The Colour scheme used for depicting wave contours in terms of wave heights is shown in adjacent figure. The brightest red corresponds to crest with maximum wave height and darkest blue corresponds to trough with maximum wave height. The values given here are unit less as they are non-dimensionalized by length of the vessel.

4.Trimaran Hull Optimization Through Modifications

4.1.Case 1: Trimaran With Centre Hull And Side Hull (52 % Of Centre Hull Length) Fitted With Wave Piercing Forms

In this particular configuration centre hull and side hulls were fitted with wave piercing bows. The draft was according reduced to match the displacement. Computation was then done for stagger (75%) and separation (8.3%). Results are presented in Fig 7 & Fig 8

4.2.Case 2: Trimaran With Centre Hull Fitted With Wave Piercing Forms And Side Hull Without Wave Piercing Forms

In this configuration centre hull was fitted with wave piercing bulb. The side hull was same as that of base trimaran. The draft of centre hull was according adjusted to match the original displacement. Computation was then done for a stagger (75%) and separation (8.3%). Results are presented in Fig 7 & Fig 8

4.3.Case 3: Trimaran With Side Hull Truncated By Aft (I.E. 35 % Of Centre Hull Length)

The centre hull of the trimaran is same as that of base trimaran but the side hull is reduced by 35 % by truncating it by aft. The draft was increased in order to match the displacement. The Cw computation was then carried out for a stagger and separation of 75 % and 8.3 %. Results obtained are given in Fig 7 & Fig 8

4.4.Case 4: Trimaran with Centre hull and Side hull(35 % of centre hull length) fitted with Wave piercing forms

The case is similar to trimaran with all hulls fitted with bulb except the length of side hull which is reduced by 35 % by truncating it by aft. The Cw computation was then carried out for a stagger and separation of 75 % and 8.3 %. Results obtained are given in Fig 7 & Fig 8

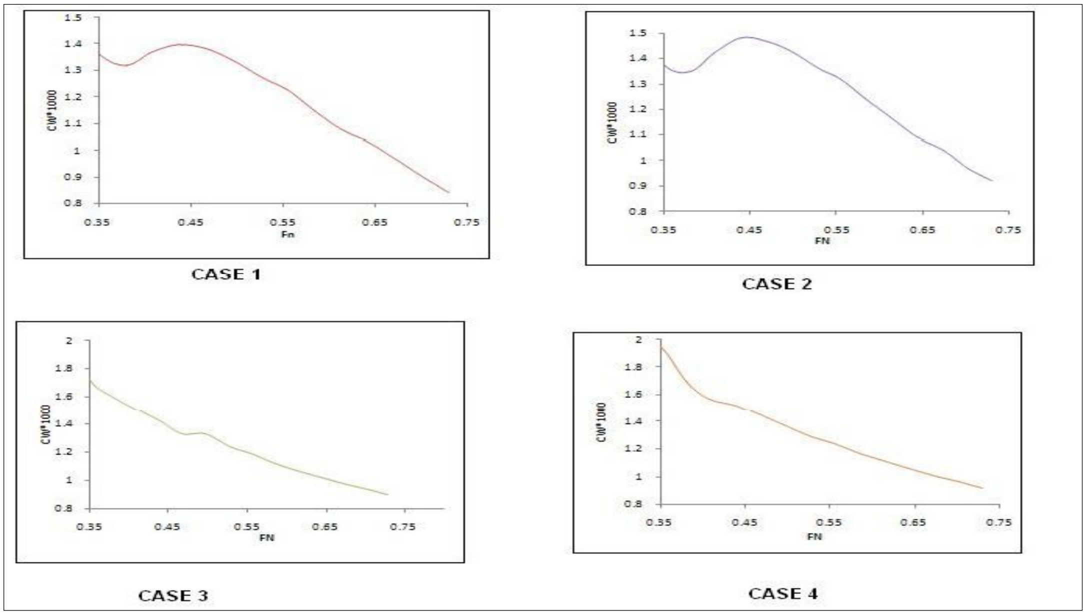

Figure 7: Cw vs Fn for various cases of optimization

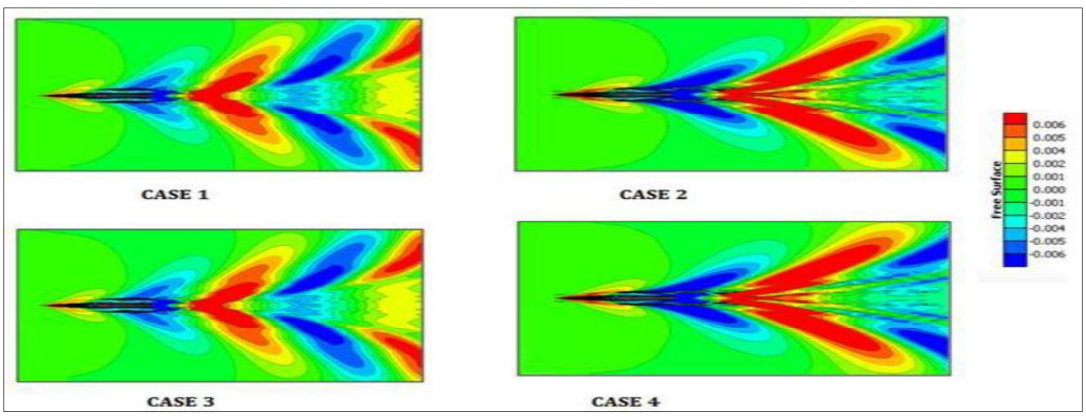

Figure 8: Wave contours for various cases of optimization

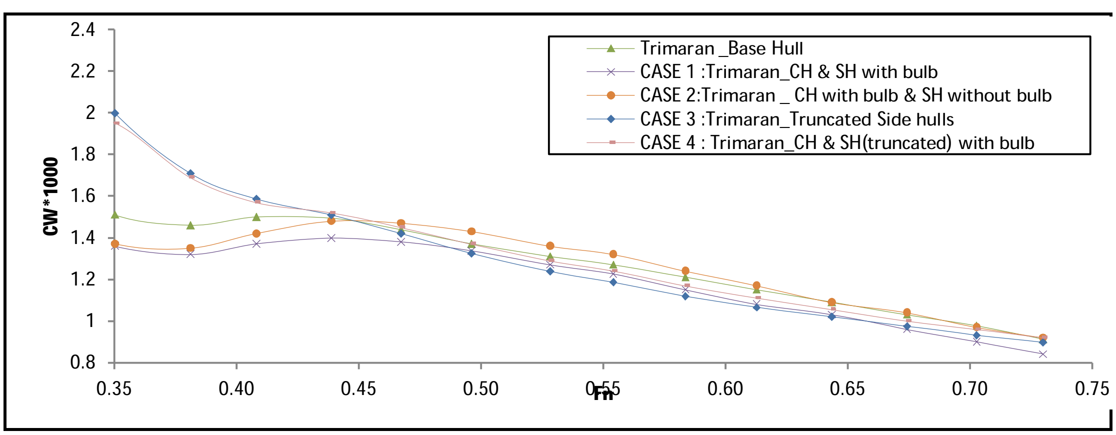

Figure 7: CW vs Fn for various cases (graphical comparison

In the end it can be conclude that it's the interference of wave system generated by centre hull and side hulls that ultimately decides the wave resistance. So the efficient design of the trimaran depends on the positive exploitation of this phenomenon.

5.Acknowledgement

We extend our sincere thanks to Dr. Lief Broberg and Mr Magnus Ostberg form FLOWTECH International AB, Sweden for their technical support in handling the Shipflow® software. Their prompt replies to your problems helped a great deal in carrying out the analysis in a smooth manner.

6.Reference

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